

AIR COMMAND AND STAFF COLLEGE

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MINIATURE MUNITIONS: IS THE US MILITARY PREPARED TO
SUPPORT MAJOR COMBAT OPERATIONS?

by

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ABSTRACT

The Small Diameter Bomb (SDB) II, also known as the Guided Bomb Unit (GBU) 53/B, is the United States (US) Air Force's newest standoff weapon to use miniature munition technology in combination with an all-weather guidance seeker designed to support a land offensive. The SDB II uses the US Air Force's new explosive material, Air Force Explosive 757 (AFX-757), in combination with target recognition software giving aircraft the capability to strike moving targets in all-weather conditions with up to four times more weapons per aircraft. Over the past decade, the US Department of Defense (DOD) has invested over \$3 billion in the SDB program. The high cost of the SDB, specifically the SDB II, dramatically reduced the number of weapons acquired when compared to older precision guided munitions (PGM). An evaluation framework is used to analyze the SDB II's ability to support a major land offensive as the only weapon. The number of weapons, cost, and production rate are compared to the Operation Iraqi Freedom (OIF) air campaign. The SDB utilizes a small warhead and is not capable of replacing larger class weapons like the 1000-lb and 2,000-lb PGMs. The main recommendation of this paper is the addition of a third miniature munition capable of replacing 1,000-lb and 2,000-lb PGMs.

Introduction

In 2001, the United States (US) Air Force Research Laboratory released a report focused on interoperability of future miniature munitions across the Department of Defense (DOD).¹ Less than five months later, the US experienced the most devastating attacks on New York City and the Pentagon and subsequently became involved in two major conflicts in Afghanistan and Iraq. In 2003, US and coalition forces began Operation Iraqi Freedom (OIF) with an aerial bombardment campaign against key Iraqi military infrastructure using precision laser and Global Positioning System (GPS) guided bombs. US and coalition ground forces were able to advance into the Iraqi capital city of Baghdad with relative ease thanks in part to the support from the air campaign. Nearly 30,000 precision and non-precision-guided munitions were employed in 28 days by the coalition attaining a coalition weapon per target ratio of 1.5:1.² The large success of the OIF air campaign would fuel the DOD's appetite for enhancing its precision-guided munition (PGM) capabilities.

In 2006, the US Air Force declared initial operational capability for miniature munition technology and employed the first miniature munition from an F-15E platform in combat.³ The introduction of miniature munition technology enhances the effectiveness of aircraft in combat by quadrupling the number of precision munitions on each platform.⁴ Two goals of miniature munitions are: to decrease the weapon per target ratio to 1.27:1 by increasing weapon reliability, and to increase the amount of munitions carried by combat aircraft.⁵

The initial phase of miniature munitions, also known as the Small Diameter Bomb (SDB) was scheduled in two increments.⁶ The SDB increment I would be the first miniature munition introduced in the US Air Force followed ten years later by the SDB II. In total, nearly 30,000 miniature munitions have been contracted by the US Air Force. The SDB development program

is currently in the second increment of development and is now testing the SDB II.⁷ The incremental approach to the SDB program builds on the capabilities of the previous increment by adding capabilities to follow-on programs.⁸ The SDB I was designed to attack fixed and stationary targets while the SDB increment II added the ability to strike moving targets in all-weather conditions.⁹

Since the 1950s, the US Air Force has relied on general purpose bombs outfitted with precision guidance kits.¹⁰ These guidance kits, which consist mostly of laser and GPS guidance kits, are mounted by military personnel to steel bomb casings ranging in weight from 500 pounds (lb.) to 2,000 lb. Once assembled, PGMs increase weapon effectiveness by improving the accuracy of each individual weapon. Precision guidance capability has been a staple of US airpower in every conflict after Operation Desert Storm in 1991.

In 1996, the US Air Force began development of a joint air launched missile with precision guidance and standoff capabilities.¹¹ During the development of the Joint Air-to-Surface Standoff Missile (JASSM), the US Air Force also developed a new type of explosive material, AFX-757, which provided significant weight and cost savings over previous explosive material.¹² A 500-lb steel bomb casing weapon holds 192 lb. of explosive material.¹³ The same effects can be achieved using only 50 lb. of the new explosive material.¹⁴ These weight savings would later enable the development of miniature munitions.

Many older precision guidance munitions force platforms to choose a weapon with either all-weather GPS and static target capability or laser-guidance capable of striking mobile targets in clear weather. In addition to GPS guidance, the SDB II also uses a tri-mode seeker giving the SDB II the capability to strike mobile targets in all-weather conditions.¹⁵

The question this research paper will answer is, “Can the SDB II replace legacy PGMs and achieve US DOD objectives in a major force on force land offensive?” The research paper

will explore the possibility of the US Air Force's newest miniature munition, the SDB II, supporting a major force on force land offensive and an additional limited conflict as the only weapon.

An evaluation framework will be used to answer the research question. The SDB II will be evaluated using three criteria to assess whether or not the SDB II is able to support a major land component offensive as the only weapon. The three criteria that will be used are mass, cost, and production capacity.

The first section of the paper will introduce the reader to miniature munition technology and its introduction to the US military. The second section will present additional background information, expand on the problem description and set the stage for the reader to comprehend why the SDB II must be evaluated to support a land offensive as the only weapon. This section will also include a literature review of pertinent sources and their relevance to the research paper. The third section will define the three evaluation criteria previously mentioned and identify the specific levels of measurement that will be used to evaluate the SDB II. This section will also evaluate the SDB II's ability to support a land component offensive similar to Operation Iraqi Freedom (OIF). OIF was the last US led, major force on force, land offensive in which US airpower played a large role. The criteria set in section three will be compared to OIF to evaluate the SDB II. This section will also discuss shortfalls and gaps in the evaluation. The fourth section will discuss the positives and negatives of the evaluation results and answer the research question. The fifth and final section will deliver a conclusion for the evaluation and present recommendations for the SDB II.

Background

On 1 October 1997, US Air Force Air Combat Command identified an operational

requirement for a new munition capable of increasing the number of kills per pass, improving capabilities in adverse weather, minimizing collateral damage, increasing capabilities against moving targets and reducing the logistical footprint.¹⁶ In 1999, as a result of lessons learned from Operation Desert Storm, the US Air Force and US Navy initiated a joint program for the development of an all-weather precision guidance system using existing bomb casings.¹⁷ This program, known as Joint Direct Attack Munition (JDAM), produced one of the top performing war capabilities for the US Department of Defense.¹⁸ The initial capabilities of JDAM only allowed for a 2,000-lb bomb to destroy a fixed target.¹⁹ Later developments of the JDAM program would include a 500-lb bomb and laser terminal guidance for the ability to strike moving targets in clear weather.²⁰

In 2005, US Air Force released an operational requirements document that supported miniature munition technology and outlined a two phase incremental introduction of miniature munitions in the United States Air Force.²¹ The incremental introduction began in 2003 with the Small Diameter Bomb Increment I (SDB I), followed a few years later by Small Diameter Bomb Increment II (SDB II).²² Miniature munitions are designed to utilize a common “smart rack” system compatible with current and future combat aircraft.²³ The common carriage system, also known as the Bomb Rack Unit (BRU) 61/A, allows both the SDB I and SDB II to be delivered using cockpit selectable options without additional modifications to the aircraft. The BRU-61/A allows aircraft to carry up to four times as many PGMs thus significantly increasing the kill per pass ratio. The SDB provides combat aircraft with the ability to engage stationary and moving targets from up to 50 nautical miles away.²⁴ This standoff ability increases aircraft survivability by allowing aircraft to remain outside engagement ranges of enemy air defenses.

The SDB I, designated as the Guided Bomb Unit (GBU) 39/B, began development in 2003 and was first introduced in combat in 2006.²⁵ Over 12,000 SDB I weapons have been

contracted by the US Air Force to date. The SDB I was designed to attack fixed and stationary targets from standoff ranges in adverse weather conditions.²⁶ Both the SDB I and SDB II were designed to deliver a small warhead using precision guidance to strike targets from standoff ranges. The SDB I only utilizes Internal Navigation System (INS) and GPS guidance which lacks the ability to strike moving targets in both clear and adverse weather.

The SDB II, designated as the GBU-53/B, was the second increment defined in the miniature munitions operational requirements document, in which the Small Diameter Bomb would gain the ability strike moving targets in adverse weather conditions in open desert or urban terrain.²⁷ The SDB II contract was awarded in 2006 and entered low rate initial production (LRIP) in 2015.²⁸ The US DOD is currently contracted to acquire 17,000 SDB II weapons over the next nine years.²⁹ The SDB is being tested for integration on the F-35 Joint Strike Fighter, the F-18E/F Super Hornet and the F-15E Strike Eagle aircraft.³⁰ Integration on the F-15E is projected to be complete in 2017.³¹ After integration is complete on the F-15E, integration testing will begin on additional projected platforms such as the F-16, F-22 and MQ-9 aircraft.

The SDB II improves on the SDB I by using a tri-mode seeker in addition to INS and GPS guidance. Like older PGMs, the SDB II uses GPS and INS guidance to initially guide the weapon within range of the seeker for terminal guidance. The seeker combines semi-active laser, uncooled imaging infrared and millimeter wave radar guidance into one seeker.³² These three guidance modes are integrated via internal software giving the Small Diameter Bomb II the capability to strike mobile targets in all-weather conditions with extremely high accuracy. The uncooled imaging infrared and millimeter wave radar guidance give the SDB II target recognition capabilities with autonomous target detection from standoff ranges.³³

The SDB II adds network centric capabilities on top of the SDB I capabilities. Network centric capabilities allow the pilot to communicate with the weapon both before and after launch

for additional weapon features.³⁴ The pilot can select the number of targets and weapons before release and also retarget the weapon(s) post release if needed.³⁵ This capability will allow aircraft and personnel on the ground to retarget or update the target location prior to weapon impact.³⁶ This feature is important for the moving target capability as the SDB II can have a flight time of approximately ten minutes and the target location will need to be updated.³⁷

The accuracy, reliability, and capabilities of US air-to-ground weapons have certainly improved on an exponential scale over the past decade, but the cost of new technology is pushing development towards expensive small warhead weapons. The high cost of this new technology may present a challenge for miniature munitions to support a major land offensive.

Problem Description

Since 2000, the US Air Force has been reducing the size of its combat force. Nearly 25 percent of fighter aircraft, 33 percent of B-1 bomber aircraft, and 20 percent of B-52 bomber aircraft have been retired as a result of budgetary reductions.³⁸ The DOD's spending on major defense acquisition programs also decreased by \$7.6 billion in fiscal year 2015.³⁹

Miniature munitions combine precision capabilities with the ability to quadruple the aircraft carriage capability.⁴⁰ This increase in carriage capability allows fewer aircraft to destroy the same number of targets if using legacy PGMs like JDAM. Increasing the number of weapons per platform by integrating miniature munition technology will increase the strike per pass ratio to a maximum of 4:1.

In addition to improving the strike per pass ratio, miniature munitions also boast an improvement in delivery accuracy and functionality.⁴¹ The increase in precision and reliability of miniature munitions allows military aircraft to destroy targets using fewer weapons. This reduction in expenditure rate will also reduce the number of weapons needed for procurement

potentially saving acquisition costs.

The improvements in weapon reliability and advanced capabilities, however, may not offset the high cost of the SDB II. The DOD may face challenges attempting to replace legacy PGMs with the SDB II. In addition to the high cost, the small size of miniature munitions will also be a potential challenge when paired to a target intended for larger class weapons.

Literature Review

Over the past 20 years, the US Air Force has advanced its PGM capability using consistent developmental projects. In 1999, the US Air Force displayed the first use of precision GPS guidance using Joint Direct Attack Munition (JDAM) during Operation Allied Force (OAF).⁴² Over 651 weapons were employed by the US Air Force's B-2 stealth bomber with an overall success rate of 87 percent.⁴³ During OAF 29 percent of munitions dropped were precision munitions. After OAF, the US Air Force expanded its inventory and reliance on PGMs. The OIF air campaign was the first air campaign in which the majority of weapons expended were PGMs.

In the closing days of OIF, Lt Gen Michael T. Mosley, USCENTAF Commander released a report detailing the number of missions and expenditure rate of the coalition. The report gives sufficient detail to accurately determine the number and type of weapons expended by the coalition, but does not reveal any specifics on target types or other information which would be useful for detailed research.

The US Air Force has been continuously improving its warfighter's capabilities to maintain the world's most capable air force. These improvements often come in the form of improved weapon capabilities. The development of AFX-757 explosive brought significant cost savings to US Air Force weapon development.⁴⁴ Even with these cost savings, miniature munitions are still much more expensive than earlier precision guided munitions like JDAM and

other laser-guided munitions. One of the main objectives of the JDAM development program was producing an affordable precision-guided weapon.⁴⁵ The JDAM project was able to produce a guidance kit, which was mounted to an existing bomb casing, for approximately \$22,000.⁴⁶ The early JDAM weapons did not possess the capability to strike moving targets, so the US Air Force developed a laser-guided JDAM (LJDAM). The LJDAM is a dual-mode weapon which uses both GPS and terminal laser guidance similar to the SDB II guidance kit, but can only strike moving targets in clear weather.⁴⁷

Gen John P. Jumper, Chief of Staff of the Air Force, realized the limitations of the current weapons when he signed the operational requirements document to fund miniature munitions.⁴⁸ This document would define the requirements and timeline for developing this new technology. Gen Jumper described the miniature munition weapon system as a “force multiplier” and critical future capability for the Air Force.⁴⁹ The SDB program boasted numerous improvements over legacy PGMs like increased reliability and an extensive warranty plan.⁵⁰

In 2006, Col Dick Justice produced a briefing outlining the capabilities miniature munitions would give the US Air Force. He explained how the Small Diameter Bomb would increase the number of kills per pass and provide combat effects in adverse weather.⁵¹ Col Justice promoted the enhancements of the SDB over current weapons, two of which included standoff capability and autonomous target attack. Col Justice’s briefing fell short on discussing funding for the Small Diameter Bomb and the difference in the DOD acquisition plan for miniature munitions and direct attack munitions. More importantly the briefing did not contain specifics on the major cost of the SDB II increment and its effect on total quantity.

The same year, the US Air Force would declare initial operational capability for the SDB I and award the contract for the second increment of the SDB program.⁵² Nearly ten years later, in 2015, the SDB II would enter low rate initial production and begin testing on the F-15E

aircraft.⁵³ The same year, Defense Acquisition Management Information Retrieval (DAMIR) would release the SDB II Selected Acquisition Report (SAR) which outlined the roadmap for the SDB II program. This document lists numerous statistics about the program including the number of weapons contracted and production timeline.

Consequently, in 2015, Mark Gunzinger and Bryan Clark released a report stressing the importance of producing and maintaining weapons with standoff capability like the SDB. This report from the Center for Strategic and Budgetary Assessments (CSBA) organization highlights the difference in DOD funding between direct attack weapons (legacy PGMs) and standoff weapons including miniature munitions.⁵⁴ Gunzinger and Clark built a case for expanded funding in the short-range and long-range standoff procurement.⁵⁵ This report takes a favorable stance with the SDB program and promotes the expansion of standoff capabilities.

Miniature munition technology does have numerous advantages over legacy PGMs, but the newest miniature munition, the SDB II, has not been adequately evaluated to support a major land offensive. The SDB II's cost and production capacity have potential limitations if the DOD intends to rely on its newest weapon to support an air campaign.

Evaluation Research Framework

The three criteria used to evaluate the SDB II are mass, cost, and production capacity. This evaluation will use the most recent US led conflict in which airpower supported a major force on force land offensive. The SDB II will be evaluated for its ability to support a conflict similar in scope to the air campaign during OIF. The amount of sorties flown and munitions expended during OIF provide a solid benchmark to evaluate the SDB II.

Following the OIF air campaign in 2003, the role of the US military evolved into counter-insurgency operations in Iraq. Due to the nature of counter-insurgency, Operation Enduring

Freedom and other operations post-OIF were not included in the evaluation. During counter-insurgency operations, special attention is usually put on minimizing collateral damage. In addition, counter-insurgency targets are different than types of targets normally seen during a conflict between two large military forces. Counter-insurgency targets are typically engaged with small type warheads due to the collateral damage concern. Heavier weapons like, the 2,000-lb class warhead, are used less frequently than during major combat operations. During OIF, the frequency of employment and variety of targets covered the full spectrum of war and provides a solid baseline for evaluation. For these reasons OIF was chosen as the baseline for the evaluation of the SDB II.

Evaluation of Small Diameter Bomb II as the Only Weapon

Criterion 1: Mass

The first criterion is mass. In order to support a major land offensive, the US military must possess enough weapons to strike an adequate number of targets to enable an effective land advance. The OIF air campaign was active from 19 March 2003 until 18 April 2003.⁵⁶ During this time, the coalition selected over 30,000 targets of which more than half (17,000) were designated directly by the Combined Forces Land Component Commander (CFLCC).⁵⁷ More than 20,000 coalition fighter and bomber sorties were flown to strike just less than 20,000 targets during the OIF air campaign.⁵⁸ On average one weapon was dropped per sortie during the campaign.

Operation Iraqi Freedom was the first air campaign in which the majority of weapons expended (68 percent) were precision guided munitions.⁵⁹ In total, 19,948 precision guided munitions were expended during the 28 day air campaign.⁶⁰ Included in this total were 802 ship-launched Tomahawk cruise missiles and 814 air-to-surface missiles including over 400 high-speed antiradiation missiles (HARM) used to protect airborne assets against enemy air defenses.⁶¹ The SDB II is neither designed nor capable of replacing these precision guided

weapons so these weapons will not be used in determining the number of total weapons required to support a land offensive.

In addition, 818 canisters of cluster bomb units were employed.⁶² Cluster bomb units are often employed on troops in the open and multiple targets in an open area. Due to the uncertainty of cluster bomb target details (types and numbers), these weapons will be assessed as requiring one weapon per target. Another category that will need modification is unguided weapons. During the campaign, 9,251 unguided munitions were delivered by the coalition.⁶³ Over 7,000 (77 percent) of these unguided weapons were 500-lb class warheads.⁶⁴ Multiple unguided weapons are often used against a single target due to the inaccuracy of unguided weapons. In order to compensate for this uncertainty, yet still account for these expenditures, only half of the unguided expenditures will be included in the evaluation. This will ensure the criteria for number of precision weapons needed for a similar conflict is not over inflated.

Using all these considerations, if a single weapon will adequately support a major land offensive the US military must possess at least 22,957 weapons prior to the beginning of hostilities. This accounts for 18,332 precision guided weapons plus 4,625 unguided weapons expended within a 28 day timeframe. During OIF, the coalition used 22,957 precision guided weapons to destroy an estimated 15,304 targets. This figure assumes a weapon per target ratio of 1.5 weapons per target (1.5:1).

The use of miniature munitions will lower the weapon per target ratio below 1.5:1 by increasing weapon effectiveness. Weapon effectiveness is a combination of system accuracy, weapon free-flight reliability, and warhead effects.⁶⁵ In the miniature munitions requirements document, a threshold value of 17 weapons per 14 targets was set for SDB weapon effectiveness.⁶⁶ Therefore, a 1.27:1 weapon to target ratio will be used for evaluation. The SDB II may actually exceed this requirement, but the worst case weapon effectiveness ratio of 1.27:1

will be used.

Using a 1.27:1 ratio, it would require 19,436 weapons to destroy 15,304 targets. In order for a single weapon to adequately support a major land offensive like OIF, a minimum of 19,500 (rounded from 19,436 for ease of computing) weapons must be in inventory prior to the beginning of hostilities.

In addition, as outlined in the 2014 Quadrennial Defense Review, the US military must also be prepared to support another limited scale conflict simultaneously. In the 2014 Quadrennial Defense Review, US forces are required to “defeat a regional adversary in a large-scale multi-phased campaign, and deny the objectives of – or impose unacceptable costs on – another aggressor in another region.”⁶⁷ The report, however, does not define what “denying objectives” or “imposing unacceptable costs” are so a rough estimate of half the quantity of a major conflict will be used for the evaluation.

This will require the US military to possess 19,500 weapons for a large-scale campaign and 9,500 (rounded from 9,750 for ease of computing) additional weapons for a limited campaign to deny or impose unacceptable costs on another aggressor. Therefore, a minimum amount of 29,000 weapons will be required to support the current US DOD defense strategy.

Criterion 2: Cost

The second criterion is cost. The US military must be able to allocate sufficient funds to acquire an appropriate amount of weapons prior to the beginning of the air campaign. The US DOD annual budget for weapon systems in fiscal year 2014 was \$1.4 trillion.⁶⁸ From 2001 to 2014, the DOD spent nearly \$17.5 billion acquiring over 300,000 direct attack PGMs (including JDAM).⁶⁹ In order to set realistic expectations for funding, similar weapon projects will be used to set a realistic value of a weapons system project. In 2014, the US Air Force allocated \$2.85

billion on the AIM-9X Block II air-to-air missile project⁷⁰ and \$3.4 billion on the Joint Air-to-Surface Standoff Missile Extended Range (JASSM-ER),⁷¹ while the US Army allocated \$3.9 billion for the Joint Air-to-Ground Missile (JAGM).⁷² In order for the US DOD to acquire a certain amount of weapons it must be less than \$4 billion for a realistic expectation.

If the SDB II becomes the only weapon, the military must allocate enough funds to acquire 29,000 SDB II weapons. At an average cost of \$131,000 per weapon, the military would need to allocate \$3.8 billion towards SDB II acquisition. Currently, the DOD has allocated nearly \$2.7 billion towards the SDB II program for 17,000 weapons,⁷³ and will need to allocate \$1.1 billion to acquire 12,000 additional SDB IIs. The AIM-9X Block II project and JASSM-ER project are specialized weapons and will not be expended at the same rate as the SDB II. A \$3.8 billion weapon project is within the normal amounts of similar weapon projects currently funded by the US Air Force. The US Air Force will be able to allocate sufficient funds to procure a sufficient quantity of SDB IIs to achieve US DOD security objectives.

Criterion 3: Production

The third and final criterion is production capacity. As outlined in the previous evaluation section, the US military must possess 29,000 weapons in order to support DOD objectives as outlined in the 2014 Quadrennial Defense Review.

From 2016 to 2020, the US Air Force has contracted to acquire 48,557 precision guided Joint Direct Attack Munition (JDAM) guidance kits.⁷⁴ As a comparison for the SDB II production, approximately 9,711 JDAM guidance kits will be produced each year during that time period. On average, 37 JDAM guidance kits will be produced per day for a period of five years.

The SDB II is currently in low rate initial production and is scheduled to manufacture less

than 600 SDB IIs each year from fiscal year 2016 to 2018.⁷⁵ In fiscal year 2019, the production rate will be increased to 1,050 weapons, and 1,650 weapons will be produced in 2020⁷⁶. From 2021 to 2025, 13,044 weapons will be produced to finish off the production cycle totaling 17,000 SDB II weapons.⁷⁷ The US Air Force will receive 12,000 SDB IIs, and 5,000 weapons will be allocated for the US Navy.⁷⁸ The difference in allocation between these two services was not considered in the evaluation as the US Navy will, in most cases, participate in the air campaign. US Naval assets may not participate in the limited scale conflict simultaneously, but this impact will be negligible. Therefore all of the 17,000 contracted weapons will be included in the evaluation.

The current schedule for 17,000 Small Diameter Bomb IIs is well short of the 29,000 weapons required to execute a major air campaign (similar to OIF) plus a limited-scale deterrence campaign. In order for the SDB II to successfully support DOD security objectives, an additional 12,000 SDB IIs must be acquired (in addition to the 17,000 currently contracted) prior to commencing an air campaign.

It is possible for the US DOD to possess less than the recommended amount of weapons, but must be able to produce enough weapons to account for the expenditure rate. For example, the US military could keep 17,000 SDB II weapons in stock and only acquire additional weapons if hostilities are expected or known in advance. This delayed strategy, however, will affect the cost per weapon as ordering fewer weapons leads to an increase in price per weapon, and will take time to begin a new weapon production cycle. A number of different situations are possible depending on multiple factors and considerations. A few of these factors include, number of weapons in stock prior to the beginning of hostilities, rate of current expenditure, and extent of employment in support of a limited scale operation.

In addition, the US military will also be required to ship the required number of SDB IIs

after production to the area of responsibility and could encounter numerous other factors during this process. For these reasons, the ability of the military to possess a partial SDB II stock prior to the beginning of hostilities will not be considered in the evaluation.

The SDB II production capacity will be evaluated post-delivery of the 17,000 currently contracted SDB II weapons. The evaluation will assume the beginning of hostilities is after the complete delivery of the SDB II weapon system and will evaluate the additional production capacity to support a major air campaign plus a limited second campaign (defined as half of the weapons used in the major air campaign). The production capacity must be able to produce an additional 12,000 weapons over a 28 day period. A maximum expenditure rate will be computed averaging 29,000 weapons over a 28 day timeframe. This is an average of 1,035 weapons per day.

Currently less than 1,000 SDB IIs will be produced in an entire year from fiscal year 2016 to 2018 (1,050 in 2018). The production rate will never increase to a level remotely close to 1,000 weapons per day even when the SDB II enters full rate production. From 2021 to 2025, when the SDB II enters full rate production, a total of 13,044 weapons will be produced. This is an average production rate of 2,608 weapons per year or 10 weapons per day, assuming 260 workdays in a year. This production schedule was set by the SDB II contract in order for the weapon to pass additional testing prior to increasing production levels in 2021.⁷⁹

The SDB II will not be able to support a major land offensive as the only weapon if the conflict begins prior to the SDB II reaching full production capacity in 2025. The SDB II production facility is a state-of-the-art robotic facility which can increase production output to meet customer demand, but producing 1,000 weapons per day is an unrealistic goal given there are only 24 hours in a day which would be 42 weapons per hour. If the SDB II manufacturer is able to produce weapons at the same rate as JDAM (37 weapons per day), only 1,036 weapons

will be produced over a 28 day period. The SDB production cycle will need to be complete prior to beginning a major air campaign.

Outliers or identified gaps

Of the 19,948 precision guided weapons expended during OIF, 6,542 GPS guided Joint Direct Attack Munitions (JDAM) were delivered, of which, all were either 1,000-lb or 2,000-lb class warheads. In comparison, of the 8,716 laser-guided munitions that were delivered, 7,114 weapons (82 percent) were 500-lb class warheads. Using a 500-lb warhead against moving targets provides more capability to attack moving targets, as the warhead is lighter and is more maneuverable than a 2,000-lb warhead. The original JDAM guidance kits were only designed for 1,000-lb and 2,000-lb warheads.⁸⁰

The JDAM guidance kit for a 500-lb bomb was not introduced until after OIF in 2004.⁸¹ Today, the US Air Force relies heavily on the 500-lb JDAM due to the reduction in collateral damage over a 2,000-lb weapon. The SDB I and II contain enough explosives to cause similar damage to a 500-lb weapon and was assumed to be capable of destroying a target intended for a 500-lb PGM.

The OIF data provided by United States Air Force Central Command (AFCENT) does not expand on additional target information concerning allowable weapon types. The AFCENT report does not contain sufficient detail to determine if a target that was destroyed by a 2,000-lb weapon could have also been destroyed using a 500-lb weapon. Due to this limitation, it is impossible to conclude if any, or all, of the 1,000-lb and 2,000-lb weapons employed during OIF could have been replaced by the SDB II during OIF.

In addition, the OIF data contained in the AFCENT report does not list the actual target types. Rather, the report lists targets in categories organized by five operational objectives.⁸² The

five listed operational objectives are air supremacy, land component objectives, suppression of Iraqi command and control, suppression of Iraqi theater missiles and weapons of mass destruction (WMD) delivery systems, and Killbox Interdiction (KI) and Close Air Support (CAS).⁸³ Seventy nine percent of targets engaged during OIF were in support of KI and CAS.⁸⁴ Targets with the ability to move are more likely to be struck in support of personnel on the ground (CAS), or in the case of OIF, in support of KI operations. Killbox Interdiction is a mission in which aircraft are assigned to specific areas in order to find and engage targets of opportunity. These targets are typically enemy troops and their equipment and are excellent targets for the capabilities of the SDB II.

The current US air campaign, Operation Inherent Resolve (OIR), was also considered for the evaluation, but the amount of weapon expenditures is much less, over a given period of time, than the OIF air campaign. In 2015, the US led coalition executed 21,113 sorties and expended 28,675 munitions for an average expenditure rate of 1.4 weapons per sortie.⁸⁵ These results are similar to the OIF air campaign but spread out over a 12 month period. Thus, the SDB II was evaluated using the OIF air campaign.

Another point to mention about the research is the two-phase structure of the SDB program. The initial phase of miniature munitions, also known as SDB, was intentionally developed in two parts that complement each other.⁸⁶ The first increment developed a fixed and static target capability and the second added an all-weather moving target capability.⁸⁷ In total, 29,000 SDBs have been contracted in the program. Since the SDB II has the potential to replace the SDB I and the SDB I is not capable of replacing the SDB II (no moving target capability), the SDB II was evaluated as a single weapon knowing the SDB program is deliberately designed to encompass both versions of the SDB.

Miniature munitions are more expensive, per weapon, than older legacy precision

guidance kits, but enjoy an extensive manufacturer warranty which will save additional costs post acquisition.⁸⁸ Miniature munitions are delivered pre-assembled and require no preventative maintenance prior to use for a minimum of five years after delivery.⁸⁹ In addition, miniature munitions also boast time savings with a requirement for 90 percent of repair tasks to be accomplished in less than one man-hour with a maximum time limit of three man-hours.⁹⁰

The small size of the miniature munitions also eases logistical processes. The weapons can be shipped in smaller containers which reduces the amount of cargo space required for transport into the conflict area. The Small Diameter Bomb contract places nearly 100 percent of maintenance responsibility on the contractor.⁹¹ This prevents the US Air Force (and US Navy) from setting up extensive logistical systems for spare parts and maintenance facilities. These savings will offset the price per SDB II weapon, but these considerations are outside the scope of research and will not be included in the evaluation.

In addition to being outfitted on fighter and bomber aircraft, the SDB can also be modified for a ground launch rocket system.⁹² Currently, only the SDB I has been modified for this capability.⁹³ The Ground Launch SDB (GLSDB) system allows personnel to mount the SDB I on an existing Multiple Launcher Rocket System (MLRS) and launch the weapon to a range of 150 kilometers (81 nautical miles).⁹⁴ This capability extends the range of the MLRS over 100 kilometers (54 nautical miles) and adds precision guidance with penetration capabilities.⁹⁵ Since this capability will more than likely be used by ground forces, it was not included in the evaluation.

Specific SDB II performance characteristics and the ability (or inability) to replace larger class weapons were not available. This aspect of the SDB II is important and is worth consideration; however, due to a lack of available research data this aspect was not included in the evaluation section. In general, a weapon with more explosives will be able to cause more

damage as a result of a larger overpressure and more fragmentation. The larger a target is, the larger the warhead must be to destroy it. Larger targets like warehouses and other large open air structures typically need a large warhead in order to cause sufficient damage. The SDB II (and SDB I) do not contain enough explosive material to destroy larger targets and will require multiple weapons per target to achieve desired results. This will negate the advantage of aircraft carrying miniature munitions. This limitation will prevent the SDB from replacing larger PGMs and force combat aircraft to carry larger class warheads.

Analysis of Research

The Small Diameter Bomb II is an advanced miniature munition capable of quadrupling an aircraft's carriage capability and attacking moving targets in all-weather conditions using infrared and millimeter wave guidance in conjunction with target recognition software. These advanced guidance modes come at a high cost. Due to the newness of miniature munition technology and price per weapon, the DOD is currently scheduled to acquire only half of the recommended amount of SDB IIs to support US DOD security objectives (a major air campaign and an additional limited campaign). The currently contracted 17,000 SDB II weapons will only be able to support 17 days of a major air campaign, in which, on average 1,000 weapons are employed each day.

The limited number of SDB IIs, however, is offset by the 12,379 SDB Is that have already been contracted by the DOD.⁹⁶ The DOD is projected to acquire 29,000 total SDBs (12,379 SDB Is and 17,000 SDB IIs), but will not possess 29,000 SDBs (the minimum recommended amount) until 2025. Therefore, if the US military is involved in a major air campaign earlier than 2025, the SDB will most likely not be able to support the campaign as the only weapon.

The main disadvantage with the SDB I, as previously mentioned, is the lack of ability to strike moving targets. The SDB I is not capable of supporting a major land offensive like the SDB II. The use of miniature munitions allows aircraft to mix the SDB I and SDB II on the same aircraft. This capability enables aircraft to use SDB I for half of the weapons and SDB II for the other half of weapons. This will still quadruple the aircraft carriage and give the aircraft an all-weather moving target capability.

The manufacturer of the SDB I, has since developed a laser-guided version of the SDB I, and has caught the attention of the US Air Force for a potential contract.⁹⁷ The laser SDB (LSDB), uses the existing seeker technology of the LJDAM which will increase production rates and lower costs for the program.⁹⁸ The LSDB, like the LJDAM, still does not possess the capability to strike moving targets in all-weather conditions.⁹⁹ The LSDB will, however, increase the amount of moving target weapons an aircraft can carry. The US Air Force should pursue the development of the LSDB as a low cost alternative to the LJDAM.

During OIF, 15,592 targets were engaged in support of KI and CAS. Assuming every target was moving or had the ability to move (worst case scenario), the DOD will acquire enough SDB IIs to engage the same amount of targets in a similar conflict. A hybrid aircraft configuration with half being SDB IIs will provide the DOD with enough SDB Is to engage fixed or static targets and also enough SDB IIs for engaging moving targets. If the US Air Force proceeds with LSDB acquisition and it is a low cost weapon, the LSDB may provide significant cost savings if miniature munitions are intended to support a major land offensive as the only weapon system.

Conclusion and Recommendations

Over the past decade, the US Air Force has transitioned from laser and GPS precision

guided weapons to miniature munitions capable of quadrupling the carriage capability of combat aircraft. This research paper provided background knowledge on miniature munitions and how the DOD has developed this technology using the US Air Force's new explosive, AFX-757.

The results from the OIF air campaign were used to determine the amount of weapons needed to support a major air campaign in addition to a simultaneous limited conflict. The research paper also explained the financial aspect of the transition from legacy PGMs to the SDB and the impact on final quantities. The financial aspect of the SDB program is a major consideration when evaluating the SDB II's ability to support a major air campaign.

The SDB II is a very advanced and capable weapon, but is not solely capable of replacing older legacy PGMs as the only weapon. The SDB program was intended to build on the successes of both increments in order to provide enough weapons and capabilities to support a major land offensive. The SDB program is projected to complete in 2025, at which point, the DOD will possess enough miniature munitions to support a major land offensive and an additional limited scale conflict. Capitalizing on both the fixed and static target capabilities of the less expensive SDB I (and possibly the LSDB) and the all-weather moving target capabilities of the expensive SDB II will allow the DOD to maximize the use of miniature munition technology. Due to the small size of the warhead, however, the SDB will not be able to support US DOD security objectives as the only weapon.

Recommendations

While the DOD is certainly capable of allocating sufficient funding (\$1.1 billion) to acquire additional SDB IIs to support a major land offensive as the only weapon, the cost of using an SDB II (\$131,000) over an SDB I (\$40,000¹⁰⁰) against a fixed or stationary target would be a waste of resources as an SDB I could be used at a fraction of the cost and achieve the same

results. Therefore, it is recommended to continue with the currently scheduled numbers of SDB I and II weapons. The SDB program is scheduled to provide the DOD with 29,000 SDB weapons, which will be sufficient to support a major air campaign and an additional limited conflict. The SDB will provide aircraft with the ability for increased kills per pass and the ability to destroy static and moving targets in all-weather conditions.

Even though SDB weapons possess significant improvements over legacy PGMs, they will not be able to replace larger PGMs like the 1,000-lb and 2,000-lb JDAM. The nature of miniature munitions utilizing a small warhead significantly reduces the explosive power of the weapon and its ability to destroy large and open air targets. For this reason alone the SDB I and SDB II will not be able to support a major land offensive as the only weapon system.

The major recommendation of this paper is a new version of the SDB to bridge this capability gap. This new version of SDB, which for this research will be labeled SDB III, should be designed to destroy targets intended for a 1,000-lb or 2,000-lb weapon. These larger class weapons are rarely employed on targets with the ability to move and thus the SDB III would only require a capability to destroy fixed and stationary targets like the SDB I. The SDB III, however, should still be developed with standoff capability like the SDB I and SDB II to remain relevant for future air campaigns. Since the SDB III will not need a moving target capability, it will not need the same complex seeker as the SDB II which will save significant costs.

The SDB III will utilize the existing miniature munition rack, the BRU-61/A, and capitalize on the benefits of the US Air Force's new explosive material, AFX-757. A BRU-61/A can be loaded with up to four SDB weapons. The SDB III will essentially combine two miniature munitions on one side of the BRU-61/A. The combining of two SDBs (front to back) will give the SDB III approximately twice the explosive power (roughly 100-lb of AFX-757) equaling around the same destructive power as a 1,000-lb weapon. The SDB III will give combat aircraft

the ability to carry three types of miniature munitions on each suspension rack (Figure 1), assuming the BRU-61/A can successfully integrate three different weapons on one rack.

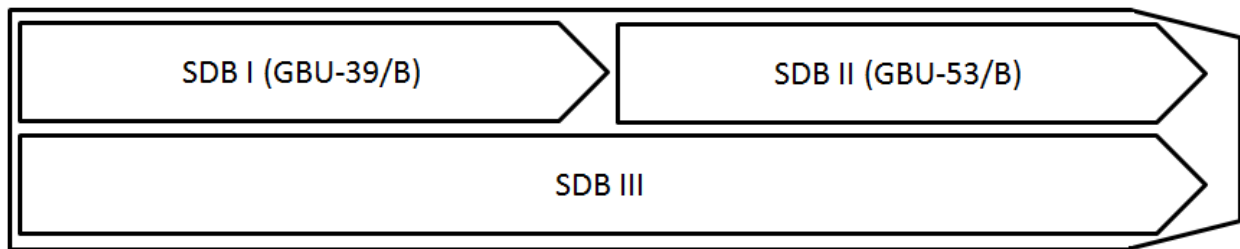


Figure 1. BRU-61/A carriage option with SDB I, SDB II, and SDB III

These three types of miniature munitions will provide the DOD with one variant of SDB with the ability to destroy fixed and static targets at a relatively low production cost, one variant to replace larger class warheads and one variant with the ability to destroy moving targets in all-weather conditions at a high cost per weapon. Using the existing suspension equipment will reduce the costs associated with a new miniature munition acquisition program and allow smooth integration with existing SDB technology. Around 6,500 heavy weapons (1,000-lb and 2,000-lb) were employed during OIF.¹⁰¹ The optimum amount of SDB IIIs will need to be explored using documentation with more specific data, like target descriptions and allowable weapon types. The results from OIR may also be used as multiple heavy weapons have been employed to support the air campaign. Adding the SDB III to the DOD inventory in sufficient numbers will then allow the US military to achieve US DOD security objectives using SDB as the only weapon.

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